



RCA INSTITUTES

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Technical Lesson 6

PRIMARY CELLS

The principal sources of electric power that are utilized in practically every radio and power installation, including transmitters, receivers, auxiliary equipment and types of apparatus of unlimited varieties, are the electric generator and the electric battery. When we say source of electric power we mean a source of electromotive force. It is customary for some persons to think that a generator or battery stores up electricity and supplies current to any device to which it may be connected, but this is not a fact. A generator or battery merely furnishes an electromotive force (or pressure) which when applied to any device, or circuit, will set electrons in motion and cause them to flow through the device, or circuit. Always keep in mind that the movement of electrons through wires (and all conductors of electricity) is the so-called current flow. Now, since electrons already exist in the wires and other elements that form a circuit then it cannot be said that a generator or battery supplies them; what the generator or battery does is to force these electrons to move through the wires from one place to another, that is, the electrons which constitute the current are forced to flow through a circuit by the e.m.f. (or pressure) applied to the circuit. Thus, it is evident that current will not flow in any circuit unless an electromotive force is applied to it from some source.

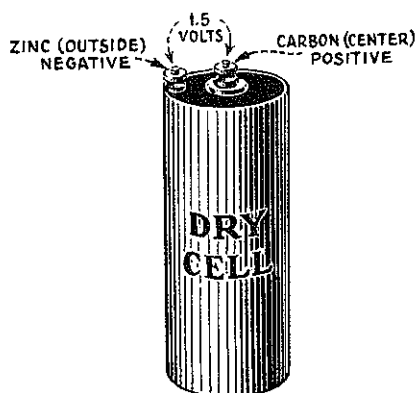


Figure 1

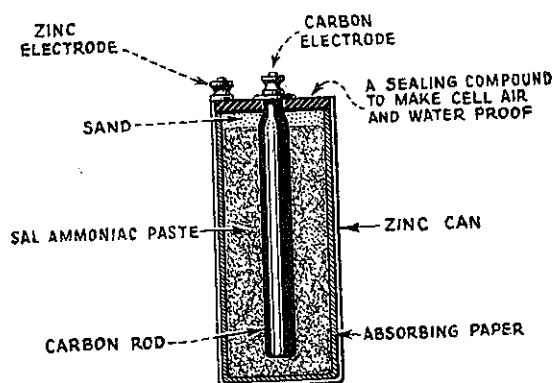


Figure 2

In the case of the generator the electromotive force is obtained by making practical use of the laws of electromagnetic induction. According to the explanations in our preceding lesson on this subject one law stated that when a coil of wire is moved through a magnetic field an electromotive force is produced across the terminals of the coil; this is exactly the principle upon which the generator works since it is constructed to provide a strong magnetic field through which a number of coils are rotated by mechanical means and from these coils we are able to get an electromotive force, or electric

power. In the case of the battery, however, the electromotive force is obtained through the electrochemical action that occurs between the combination of materials that are used. We learn, therefore, that a generator transforms mechanical energy into electrical energy and a battery transforms chemical energy into electrical energy.

Hence, insofar as we are concerned at the present, a generator and a battery both produce similar results, that is, either one will provide an electromotive force. Of course, you will understand that many practical and economical considerations determine whether a generator or battery will be used to furnish power for the operation of certain types of equipment. In many of the modern radio broadcast and commercial telegraph installations it has been found necessary to employ both generators and batteries to obtain the best electrical results.

CLASSIFICATION OF BATTERIES AND CELLS. Let us first explain the distinction between the terms "battery" and "cell". A cell is a complete unit consisting of a chemical solution into which is placed two different kinds of materials which are not allowed to touch each other and from which an electromotive force can be obtained by the chemical action set up between the solution (electrolyte) and the materials. When two or more cells of similar kind are connected together in a combination that permits their individual e.m.f.'s to be utilized all at the same time, the whole combination is known as a "battery". Hence, a battery is a number of cells all functioning in conjunction with one another to provide a certain amount of electrical pressure, measured in volts, from its terminal binding posts.

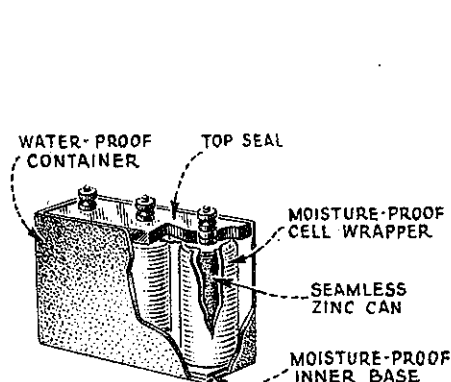


Figure 3

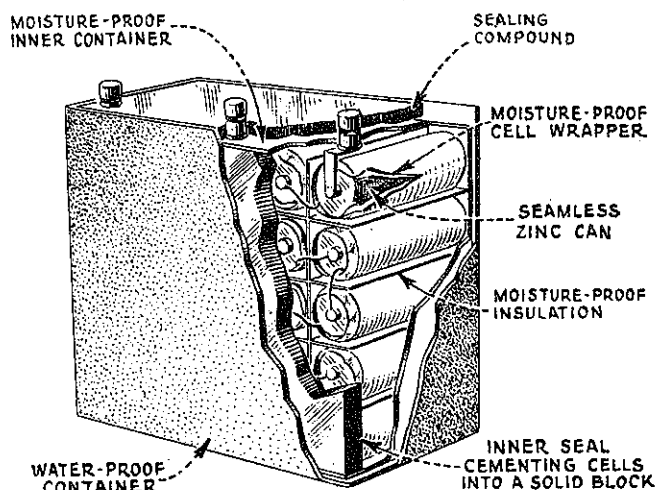


Figure 4

A single cell of the dry cell type is shown in Figure 1 while its interior construction is pictured in the cross-sectional view in Figure 2. This cell has an e.m.f. of approximately 1.5 volts when in good condition. Several cells may be connected to form a battery as follows: Suppose we have 3 cells of this type connected together to form a battery then the total e.m.f. at the terminals would be 3×1.5 or 4.5 volts. Again, suppose we had 30 cells of this kind connected to form a battery then the total e.m.f. available at the battery terminals would in this case be 30×1.5 or 45 volts. In many dry batteries there are connections taken from different cells in order to provide several different voltages from the same battery for convenience.

A battery consisting of three small dry cells connected together in series is shown in Figure 3. Notice that three terminals are supplied so that the e.m.f. (or voltage) of either cell may be used separately, or the voltage of the two cells may be used by making connections to the outer two terminals. A dry battery containing thirty small cells compactly arranged in a container is shown in Figure 4; the e.m.f. at the outside two terminals is 45 volts. In this battery a tap taken between the 15th and 16th cells is brought to the center terminal on the top so that one-half of the total voltage, or $22\frac{1}{2}$ volts, is available either between the first and second terminals, or between the second and third terminals.

The dry cell and batteries illustrated are typical of the kind found in widespread use for radio and electrical work. A battery similar to the one in Figure 3 is mostly used for a specific purpose in radio circuits to supply a negative voltage to the grids of vacuum tubes and it is, therefore, known as a "C" battery. The battery in Figure 4 is exactly the same as the one just mentioned so far as its principles of construction are concerned, except that it has more cells than the one in Figure 3. The larger battery in Figure 4 is employed principally to furnish the plate voltage to operate vacuum tubes in certain types of equipment and, consequently, it is known as a "B" battery. If several cells of the type in Figure 1 are used to furnish an e.m.f. to the filaments of vacuum tubes in receiving sets, to provide the heating current, the cells are then referred to as an "A" battery. Later on in your work you will become accustomed to using the terms "A", "B", and "C" for identifying batteries of any type according to their particular duty. It should now be clear that the terms battery and cell are not to be used interchangeably and, therefore, in your conversation and writing be careful to make the correct distinction between them. Say "cell" when you mean cell and "battery" when you mean battery.

DISTINCTION BETWEEN PRIMARY AND SECONDARY CELLS. There are two types of cells in general use, namely: dry cells and storage cells. A dry cell is one that depends for its operation upon the consumption of one of the materials by the chemical action of the solution on it when current flows through the cell and through the circuit to which it is connected. While current flows the material is gradually eaten up and in due time it will be entirely consumed and as a result of this action the voltage (or e.m.f.) of the cell will drop so low that the cell becomes useless for all practical purposes. When this happens the cell must be discarded and replaced by a new one. A storage cell, on the other hand, is one that must first be charged by passing a current through it in a certain direction so that its materials will be put into the proper condition that will enable them to produce an electrical pressure. After the storage cell has been on circuit and delivers a certain amount of current in a stated time, its e.m.f. will fall below the proper working value because the chemical relations of the cell are then altered. Since the materials merely undergo a change and are not eaten away, as in a dry cell, it is only necessary to pass current again through the storage cell to restore the materials to their original condition. With intelligent care a storage cell will last for years since it only requires charging and the adding of water at periodic intervals to maintain it in a proper condition. The life of a dry cell, on the other hand, is a more or less fixed condition because it is governed by the rate at which the active material, zinc for instance, is consumed and this in turn depends upon the amount of electrical energy delivered by the cell. For the reasons just

advanced a dry cell is called a primary cell and a storage cell is called a secondary cell. A lesson is devoted to storage batteries and storage cells later in our course. Primary cells are also known as galvanic cells.

Another important thing to mention is that a dry cell is not really dry as the name would lead most anyone to believe. The use of the word "dry" no doubt became popular owing to the fact that all of the materials in the cell are sealed up in a moisture-proof container without any outside evidence of a liquid solution in it like in a "wet" battery, for example. During the manufacture of a dry cell a certain amount of water is added to the materials and the liquid is therefore retained in the moist pasty filling which we could see if we broke open a good cell.

WHY AN ELECTROMOTIVE FORCE IS PRODUCED BY A DRY CELL. It is a known fact that there is always an e.m.f. of a certain number of volts set up between any two pieces of metal of dissimilar kind when immersed in a liquid. When certain combinations of materials are used, and the liquid is a chemical solution of a particular kind, e.m.f.'s as high as 2 volts and more can be obtained. The metal pieces referred to are called "plates" and the chemical solution the "electrolyte". The e.m.f. or voltage of a cell is determined solely by the kind of materials used for the plates and the nature of the electrolyte. The theory is that the electrolyte acts more readily on one material than the other and it is this chemical action that causes both plates to possess an electric potential, but because of their difference in character one plate will have a higher potential than the other. The higher potential plate is called the positive plate and the lower potential plate is the negative plate. The difference of potential is electrical pressure and it is capable of sending current through a circuit. The size of the plates, their actual surface area in contact with the electrolyte, or the amount of separation between plates have no bearing whatsoever on the voltage of the cell. However, these factors do have some effect on the internal resistance of the cell and this in turn will govern to some extent the amount of current that the cell will be capable of delivering.

Hence, if we have one very large cell and one very small cell and each one is made up of a similar combination of materials and electrolyte it will be found that the voltage reading taken between the plates will be alike for the two cells. This would prove our statement that only the materials and the electrolyte govern the e.m.f. or voltage across the plates. A cell consisting of a zinc plate and a copper plate immersed in a liquid of dilute sulphuric acid gives an e.m.f. of approximately 1 volt regardless of the size of the elements (elements means the materials). Another cell, however, having a different combination of materials, for instance, zinc for one plate carbon for the other, and a sal ammoniac electrolyte, sets up an e.m.f. of approximately 1.5 volts between its plates.

POLARIZATION. To explain this term let us consider that we have a cell consisting of a zinc plate and a carbon plate being acted upon by a sal ammoniac electrolyte solution. When a cell of this type is connected in a circuit and current flows the zinc is slowly dissolved, or eaten up, by the chemical action of the sal ammoniac (ammonium chloride). It is the combining of the electrolyte chemically with the zinc and the amount of the intensity of the action for this particular set of materials that makes the cell capable of developing an e.m.f. between its plates and, also, to furnish a given amount of current to a circuit for a given time.

While the chemical action goes on and current flows through the cell a quantity of fine bubbles of hydrogen gas are liberated which immediately form around the carbon. The bubbles collect very rapidly if the cell passes a current of high value continuously for any length of time and their presence on the positive carbon plate causes a very noticeable reduction in the current strength. Thus, we see that the hydrogen gas has a detrimental effect on the amount of electrical energy supplied by the cell. This weakening of the cell is called polarization and if allowed to continue the cell will cease functioning entirely.

The falling off of the current caused by the hydrogen gas is due to two conditions set up within the cell; first, the gas being a non-conductor of electricity acts as an insulator and increases the internal resistance of the cell and, therefore, actually tends to block the flow of current; secondly the gas layer on the carbon reduces the amount of active surface material that the carbon can present to the electrolyte, that is to say, the gas acts to separate the carbon from the electrolyte. Moreover, if a cell of this kind is strongly polarized it sets up a small opposition e.m.f. because the character of the plates are altered inasmuch as the carbon plate virtually becomes a hydrogen plate. So far as the chemical action of the cell is concerned it will behave as though it had zinc and hydrogen plates and not zinc and carbon. It has been mentioned before that different combinations of the materials of which a cell is composed will cause the e.m.f. produced between its plates to also change, hence, the e.m.f. of the cell is considerably lowered by the polarized condition.

Polarization is prevented in a cell when it is operated to give an intermittent current of average value for the particular type of cell in question. In the type already under consideration a strong oxidizing substance, such as manganese dioxide, is used for this purpose as it combines readily with the hydrogen and, therefore, removes the gas from around the carbon. It is to be understood that if an excessively large current is delivered steadily by the cell the chemical action between the oxidizing material and the hydrogen may be too slow to prevent polarization and the cell will become inactive in a short time. However, if a cell when in this condition is disconnected from the circuit and permitted to remain on open circuit for a brief interval it will rapidly recuperate, or recover, which means that it will be restored to normal by the cleaning up of the hydrogen by the depolarizing agent. The carbon then is once more left free to act as a plate and conductor for the passage of current.

Have you ever noticed when using a pocket flashlight that the light suddenly became dim, but after allowing the switch to remain in the "off" position for a half minute or so the lamp when next lighted would glow with its former brightness? This dimming of the light was caused by the falling off of the current through the cell due to polarization. The same weakening effect is often noticed in the ringing of a door bell, or in the operation of a buzzer, especially when they are operated steadily for a time.

LOCAL ACTION. If a cell, like the one pictured in Figure 5, is left on open circuit (which means that there is no conductor of electricity connected to its respective plates) then there should be no chemical action occurring between the materials composing the cell. If the zinc plate is absolutely pure (i.e., without foreign matter or impurities) an internal action cannot be set up and current cannot be produced by the cell's own materials. However,

ordinary commercial zinc contains many foreign particles, such as carbon, tin, iron, and so on, and these small foreign particles act with the zinc to set up tiny electrical currents that flow in a short-circuit path as shown in Figure 5. This local action causes the zinc to be eaten away continuously and in time it will affect the normal output energy of the cell. To prevent this consumption of the zinc when the cell is not used to operate a circuit it is customary to rub a small quantity of mercury into the surface of the zinc. This process is called amalgamation. Amalgamation, therefore, stops local action when a cell is left on open circuit because the mercury does not combine with the carbon, or other foreign particles, but it does act chemically with the zinc to form zinc-mercury amalgam that works its way over the zinc plates and covers up the particles.

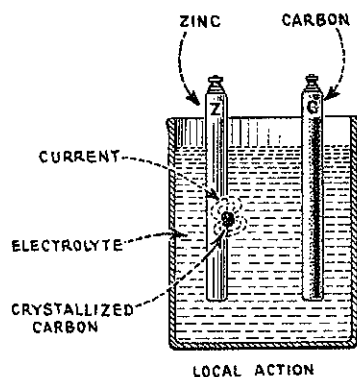


Figure 5

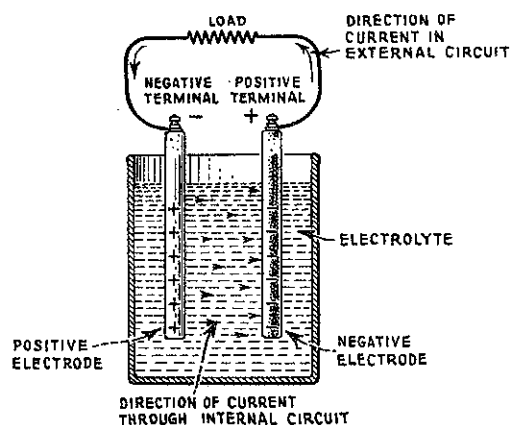


Figure 6

ACTION OF A SIMPLE PRIMARY CELL. Suppose the simple cell in Figure 6 is composed of a positive copper (Cu) electrode, a negative zinc (Zn) electrode, and diluted sulphuric acid. In this combination of materials the acid unites more readily with the zinc than with the copper. The chemical symbol for sulphuric acid is H_2SO_4 which denotes that a molecule of this liquid consists of two atoms of hydrogen, one atom of sulphur, and four atoms of oxygen.

The action is explained according to the "electron theory". The important thing to bear in mind is that atoms consist of an aggregation of electrons and if some of these electrons can be set free by chemical means the free electrons will move through the conductors forming the external circuit around the cell. As we have just stated the movement of current through the load circuit connected to the cell is simply a movement of electrons. Their direction of flow in the external circuit connected to a cell is from the negative terminal to the positive terminal of the cell. This is in accordance with the theory as explained in our lesson on "Static Electricity". It was stated that at a positively charged electrode there is a deficiency of electrons and at a negatively charged electrode there is a surplus of electrons.

We will attempt to make the following explanation as easy to understand as possible although it is not necessary that you learn this explanation. When chemical action sets up in the cell each molecule of sulphuric acid separates into two oppositely charged parts; namely, positive ions which are the H_2 or hydrogen part of the acid, and negative ions which are the SO_4 or sulphuric part of the acid. The negative ions are made up of a certain number of

negative electrons. Also, a portion of the zinc separates into electrons and positive ions with the latter uniting with the negative sulphate ions, the SO_4 mentioned above. But the electrons just made available by the zinc do not unite with other parts and, therefore, they move through the circuit. The repulsive force which electrons exert upon one another (this is because all electrons possess a negative charge of equal amount and have similar characteristics otherwise) causes them to move through the zinc electrode, and through the conductors forming the external circuit, and thence through the copper electrode and the action just described continues on so long as the cell is connected to the external circuit and the materials used in the cell are in good condition. (The external circuit consists of the connecting leads and the load as indicated by the resistance symbol.) The fact that each one of the two parts of the electrolyte go to opposite plates when it separates as stated above (that is, the H_2 positive ions go to the copper plate and the SO_4 negative charges go to the zinc plate) causes the respective plates to become charged electrically to positive and negative potentials. This results in the setting up of a difference of potential between the plates, or terminals, of the cell and the movement of the electrons through the external circuit in the direction from negative to positive.

The arrows in the drawing in Figure 6 are not to be associated with the movement of the electrons in the explanation just given. The arrows merely indicate the direction of current flow according to the usual convention or custom in practical use for many years. Note that the current arrows are in a direction in the external circuit from the positive to the negative electrode and in the internal circuit from the negative to the positive electrode.

CONSTRUCTION AND OPERATION OF THE COMMON DRY CELL. The interior view of a typical dry cell is plainly marked in Figure 2 to identify all of the parts that enter into its construction. Dry cells of this type are usually 6 inches high and $2\frac{1}{2}$ inches in diameter. The zinc cylindrical can is the negative electrode. The terms electrode and plate are used interchangeably. The zinc can holds the moist black paste into which is embedded a large carbon rod that forms the positive electrode, or plate. The paste usually consists of a mixture of ammonium chloride (or sal ammoniac, the chemical name of which is NH_4Cl), plaster of Paris, powdered coke, a small quantity of graphite, zinc chloride (ZnCl_2), and a de-polarizing agent, such as manganese dioxide (MnO). Enough water is added to the electrolyte to moisten the absorbing paper which lines the zinc can and separates the zinc from the paste. After the paste and carbon rod are firmly packed in, the whole assembly is covered with sand and on top of this is placed a sealing compound to make the cell moisture proof and thus prevent evaporation.

The great advantage of this type of cell is that it can remain on open circuit for long periods without appreciably shortening its useful life. After a period of a year, or more, it will begin to deteriorate rapidly if unused and the drying out of the cell will be hastened if it is kept in a very warm atmosphere. It is always best to keep a dry cell in a cool place whenever possible where the temperature is not much higher than 70°F .

A dry cell is a very convenient means for obtaining an electromotive force but it is adapted only for use on intermittent work such as, ringing door bells, telephone installations, or where the service demands only a small

continuous current such as for supplying current to heat the filaments of small receiving type vacuum tubes in radio circuits, and other uses too numerous to mention.

Because of its low internal resistance a dry cell in good condition will deliver a current of about 18 to 30 amperes, or more, when measured on momentary short circuit by means of a low resistance ammeter. Short circuit tests should not be made often on the same cell as it places a heavy drain on the active materials. A voltage test can be made by using a good high-grade voltmeter with a low reading scale. The average e.m.f. of all new dry cells in good condition is about 1.5 or 1.6 volts. In certain classes of work after a cell has dropped to about 1 volt it is removed from active service and a new one is substituted. Also, if two or more cells are used in conjunction with one another their individual voltages should be measured frequently to ascertain whether they are nearly alike, or whether one cell is considerably lower than the rest in which event the operation of the circuit would be seriously impaired.

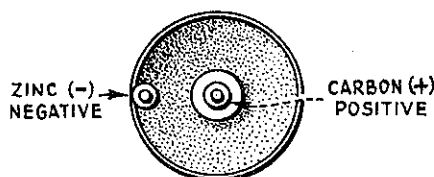


Figure 7

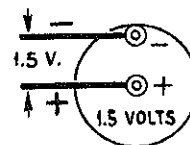


Figure 8

LECLANCHE CELL. The standard dry cell is practically a Leclanche' cell made up in a different form — both employ similar materials in their construction. The Leclanche cell consists of two cylindrically shaped plates, one of zinc and one of carbon placed in a sal ammoniac solution, the carbon plate being corrugated in shape to form a porous cup in which the manganese dioxide and powdered coke are placed. When delivering current the sal ammoniac solution attacks the zinc and, as in the case of the simple dry cell, bubbles of hydrogen gas are liberated and collect on the surface of the carbon. The gas combines with the manganese dioxide and is removed, thus preventing polarization of the cell. A cell of this kind will keep in good working condition for years and practically the only attention it needs is an occasional filling with water and sometimes with a fresh supply of sal ammoniac.

METHOD OF CONNECTING CELLS.

A top, or plan view, of a common dry cell is shown in Figure 7. The center terminal connects to the carbon rod and this terminal is called the "positive pole" of the cell; the (+) sign is used to denote positive polarity. We do not as a rule call this a "plus" sign in this work; we most generally say "positive" sign. The terminal at the outer edge of the cell connects to the zinc can, or shell, of the cell and this terminal is called the "negative pole"; the sign (-) is used to denote negative polarity. We do not call this a "minus" sign as a rule but rather a "negative" sign. Hence, we say that a dry cell has two terminals, one a positive and the other a negative. The small sketch to the right in Figure 8 is one way of drawing the top view of a cell and indicating the amount of electromotive force in volts that the cell is rated at, or in this case, the cell is seen to have a "terminal" e.m.f. of 1.5 volts. Instead of drawing a picture of a dry cell each time we

desire to indicate one on a diagram we make use of the standard symbol as shown in your lesson on "Symbols". The long thin line represents the positive pole, whereas, the short heavy line represents the negative pole.

There are two ways in which the cells of a battery may be arranged to vary the current output of the cells; (1) By a series combination; and (2) by a parallel combination.

- (1) By the series method the e.m.f. of the battery is increased because the single cells are connected in a way that permits the sum of all of their e.m.f.'s to be available. When cells are joined in series the internal resistance of the combination is equal to the sum of the internal resistances of the individual cells. In Figure 9 three cells are shown joined in series and connected to a bell.
- (2) By the parallel method the e.m.f. of the battery will not be greater than that of a single cell but the internal resistance of the battery decreases with each addition in the number of cells used. Refer to Figure 10 showing three cells joined in parallel and the combination connected to a bell and controlled by a push button.

SERIES COMBINATION.

Both Figures 9 and 10 are pictorial diagrams drawn to assist you in understanding just how the cells are actually connected. Notice that in the series combination in Figure 9 the connecting wires are put on according to the following system: The negative terminal post of cell 1 is joined to the positive of cell 2; the negative of cell 2 is joined to the positive of cell 3; the negative of cell 3 is joined to one terminal on the bell; the other bell terminal is joined to one terminal on the push button; the other terminal on the push button is connected to the positive terminal of cell 1. Thus, we have made a complete circuit, beginning at cell 1 and returning to

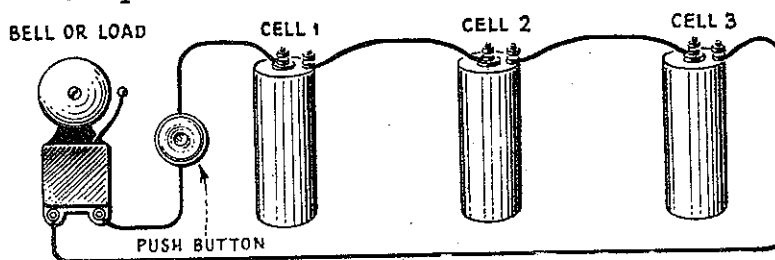


Figure 9

it. In this arrangement the same amount of current that flows through one part of the circuit must also pass through all other parts since there is only one continuous circuit formed. Now refer to the diagram in Figure 11 which illustrates the circuit in Figure 9 in slightly different form. The purpose of Figure 11 is to show that when we connect two cells from positive to negative we are in reality connecting the carbon of one cell to the zinc of the adjoining cell. It is a simple matter to trace out the "continuity" of this circuit. The word "continuity" expresses just what we were doing, that is, tracing out a circuit from beginning to end to see that it is continuous and unbroken so that we may be sure that current will flow through

all of its parts. The course of the current is shown by the arrows.

Now let us study the schematic diagram in Figure 12 showing 3 cells joined in series. If each cell has an e.m.f. of 1.5 volts the sum of the e.m.f.'s will determine the amount of voltage available at the output terminals, or in this case, 3×1.5 equals 4.5 volts, as marked on the diagram. Consider the group of cells joined in series in Figure 13, the voltage supplied to any circuit connected to the two outside terminals of this battery, marked + and -, would be 6×1.5 , or 9 volts.

Figure 14 illustrates series groupings of cells similar to those already given but they are drawn in slightly different form. The single cell at the left is shown to point out the relation between a cell and its symbol. We have arranged these diagrams in slightly different form so that you will be-

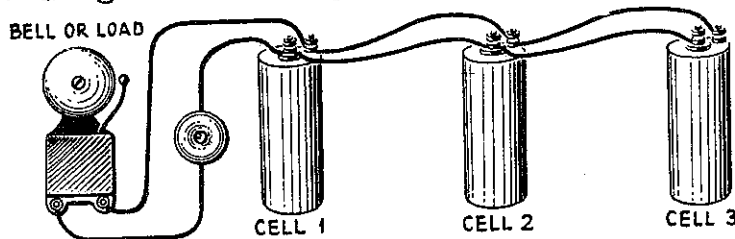


Figure 10

come accustomed at the very start of your work to read a schematic diagram drawn in any manner.

Example: Suppose we have a battery consisting of 12 cells, each rated at 1.5 volts, with the cells in series. What is the total voltage available? The answer is 12×1.5 , or 18 volts. Example: If the internal resistance of each of the cells in a group of 12 connected in series is 0.5 ohm, what is

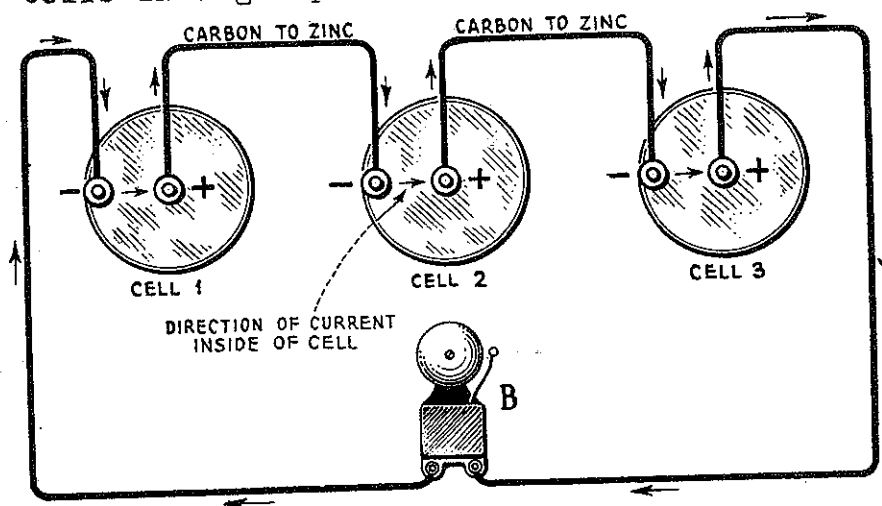


Figure 11

the total internal resistance of the cells? The answer is 12×0.5 ohms, or 6 ohms.

From the foregoing explanations we learn that to find the resultant voltage, or e.m.f., of any number of cells connected in a series combination it is only necessary to multiply the voltage of any one of the cells, providing

they are all alike, by the number of cells in the group. Also, to find the internal resistance of all of the cells taken together in a series combination we must multiply the internal resistance of one of the cells, providing they are all alike, by the number connected in the group.

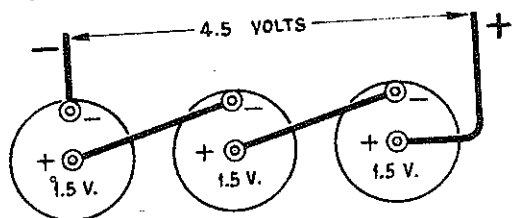


Figure 12

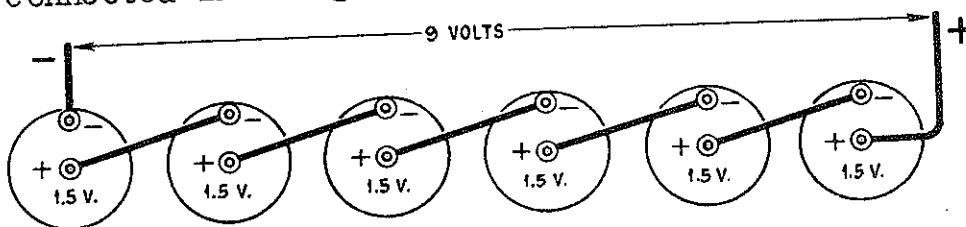


Figure 13

The drawing in Figure 15 of the three locomotives moving a heavily loaded box car is presented as an easy way for most persons to visualize how the total pressure applied to the car is the sum of the individual forces that each locomotive is exerting. Suppose the box car were a long train of cars, and it was found that one locomotive could only move the train very slowly, then, by coupling a second locomotive to the first there is no doubt that the train could be moved at a faster rate and, again, if a third locomotive were coupled to the first two the train could be moved at a still faster rate. We have a similar condition in an electric circuit when cells are connected in series, the voltage of every cell in the battery contributes its pressure

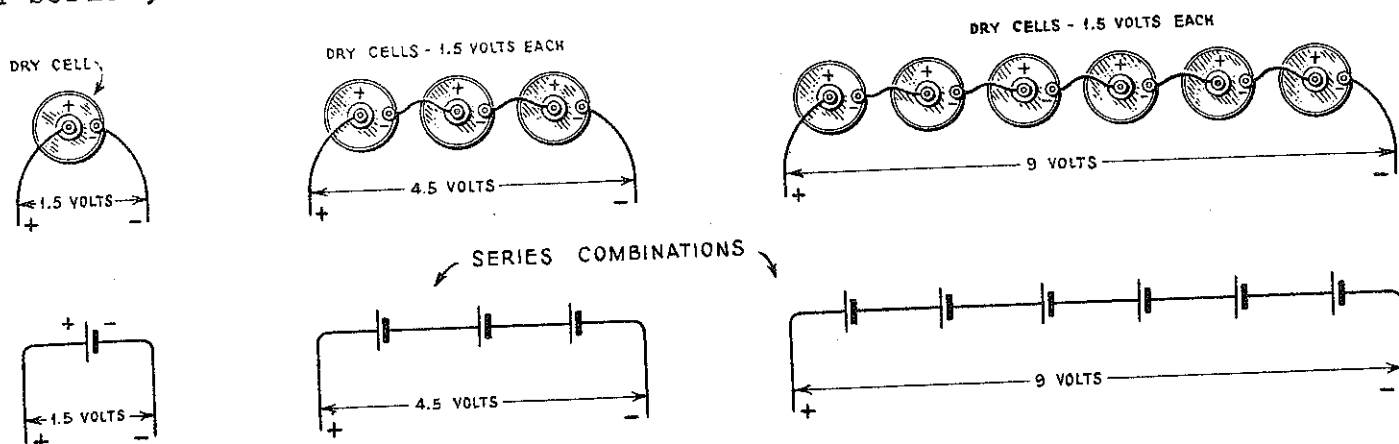


Figure 14

additively and since a larger voltage is available a strong current can be forced through a given circuit to perform a certain amount of electrical work.

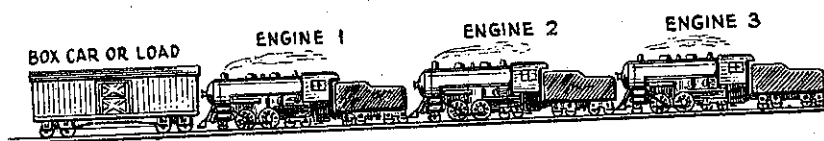


Figure 15

PARALLEL COMBINATION.

Figure 16 is a picture diagram of a parallel or multiple grouping of cells where the e.m.f. or voltage of the whole combination is only the e.m.f. of a single cell. The drawing shows that all of the negative terminals (—) are

connected together and, therefore, we have but one lead coming from the negative side of the cells that is common to all of negatives. The positive terminals (+) are also all connected together which provides only one common lead coming from the positive side of the cells. Observe that the connecting wires are put on according to the following system: The zinc of cell 1 is joined to the zinc of cell 2; the zinc of cell 2 is joined to the zinc of cell 3; and from this point a lead is carried to the bell. Next we have the carbon of cell 1 joined to the carbon of cell 2; the carbon of cell 2 joined to the carbon of cell 3; and then a second connection is carried from this point to the other terminal on the bell. Thus, we have completed the continuity of this parallel arrangement of cells. The path of the currents furnished by the individual cells and the total current flowing to the bell is represented by the arrows.

In this arrangement the internal resistance of the battery is reduced if cells are added to the group. For example, the internal resistance of the 3 cells in the battery in Figure 16 is one-third that of any single cell. If there are two cells in a parallel grouping, as in Figure 17, the internal resistance is one-half that of either cell.

We learned in the first part of this lesson that the amount of zinc exposed to the action of the electrolyte determined the amount of current that would be delivered by the cell and that the voltage of all cells are exactly alike, regardless of their size, when the same combinations of materials are employed. Hence, in a parallel grouping of cells we have the effect of increasing the area of the plates since the zincs of all the cells are connected together; but we do not obtain an increase in the e.m.f. according to the consideration that certain combinations of materials give a known e.m.f. and the size, or area, of the materials has no influence on this voltage. The advantage of connecting cells in parallel is that each cell contributes an equal amount of the current delivered by the battery.

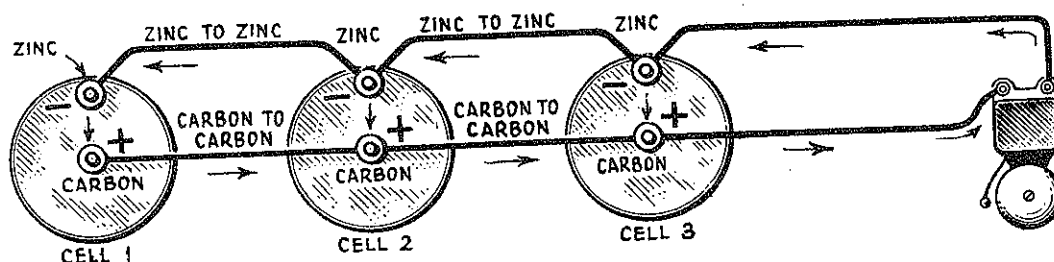


Figure 16

Hence, suppose the battery in Figure 18 consisting of 4 cells in parallel is connected to a circuit which is passing 2 amperes, then each cell of this group would contribute one-fourth of 2 amperes, or 0.5 ampere to the circuit. Thus, the load would be divided equally among the cells. If all of the cells were forced to pass 2 amperes through them to supply such a circuit the cells would deteriorate very rapidly. In Figure 16 suppose the actual current passing through the bell is 0.15 amperes; each cell then would furnish one-third of this amount, or $0.15 \div 3$ equals 0.05 amperes.

Figure 19 shows two parallel combinations of cells. The e.m.f. of the left-hand battery is 1.5 volt, or the e.m.f. of any one of the cells; and the e.m.f. of the right-hand battery is also 1.5 volt, or the e.m.f. of any cell in the group.

The water analogy in Figure 20 gives a clear idea of the effect of connecting cells in parallel where the pressures are not added up but each cell merely contributes its share or quantity of current to the circuit to which it is connected.

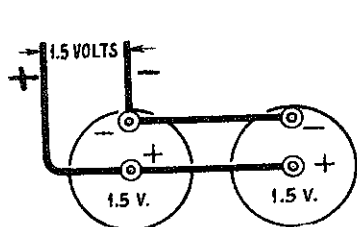


Figure 17

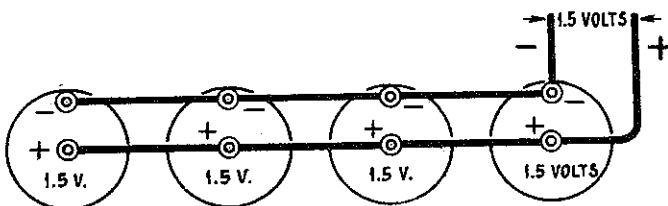


Figure 18

Suppose tanks T_1 , T_2 , and T_3 each supply 10 gallons per minute; the total quantity of water running over the wheel will be 30 gallons per minute, but the pressure will not be greater than that furnished by any one of the three tanks.

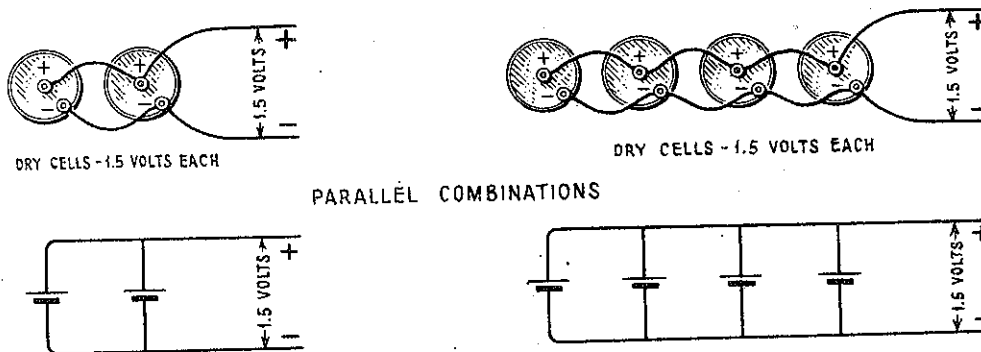


Figure 19

Parallel-Series Combination. The schematic diagram in Figure 21 shows 9 cells connected in a parallel-series arrangement. In this circuit we have three separate series groups each of which consists of 3 cells connected in series, and the three series groups are joined in parallel. By reading the diagram we see that a parallel-series combination is a parallel connection of a number of series arranged cells.

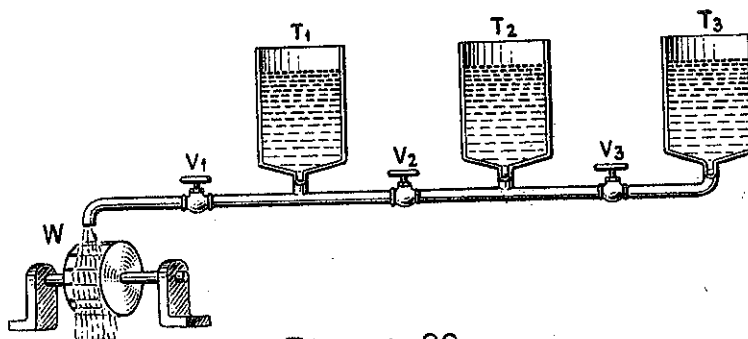


Figure 20

The e.m.f. across each series connection is 4.5 volts. In a parallel combination of cells the e.m.f. is the same across the component parts, hence, the e.m.f. across the three groupings is 4.5 volts as marked on the diagram.

Series-Parallel Combination. The circuit illustrated in Figure 22 consists of 12 cells connected in a series-parallel arrangement. Observe that there are three separate parallel groups each of which consists of 4 cells connected in parallel, and the three parallel groups are joined in series. Hence, a series-parallel combination is a series connection of a number of parallel arranged cells.

The e.m.f. across the battery in Figure 22 is 4.5 volts because the e.m.f. across each parallel group is 1.5 volts, i.e., the total e.m.f. of the 3 groups in series is their sum, or 4.5 volts, as marked on the diagram.

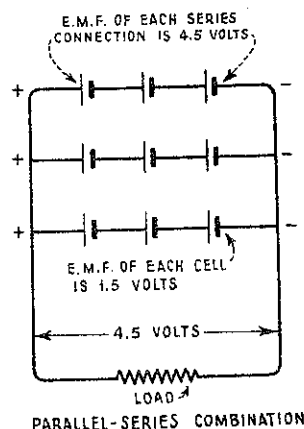


Figure 21

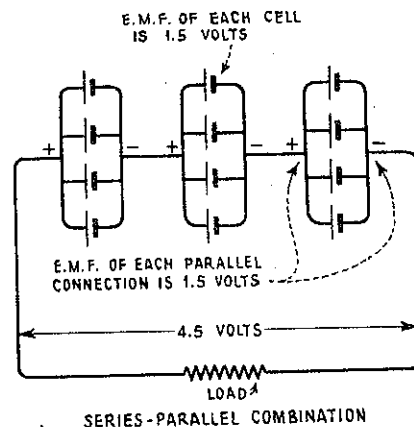


Figure 22

SUMMARY. The principal facts that should be remembered from this lesson are listed below. In our lesson on "Electrical Circuits and Ohm's Law" the mathematical relation between the resistance, the voltage and the current in a circuit will be explained. It is advisable that you practice drawing cells in various combinations so that reading simple schematic diagrams will not cause you any confusion.

In a primary cell one plate is consumed by the action of the electrolyte when the cell produces an e.m.f.

Polarization is caused by a layer of hydrogen gas bubbles collecting on one of the plates.

Local action is due to impurities and foreign particles such as carbon, iron etc., in commercial zinc.

Results Obtained From Various Cell Combinations.

VOLTAGE - RESISTANCE - CURRENT

SERIES arrangement of cells.

VOLTAGE....The total e.m.f. of a series combination of cells is the sum of the e.m.f.'s of the individual cells.

RESISTANCE.The internal resistance of cells in series is increased by adding cells. The total resistance is the sum of the internal resistances of the individual cells.

CURRENT....In practice cells are usually connected in series (to increase the e.m.f.) when the resistance of the load circuit (or external circuit) is high in order to obtain a large current.

PARALLEL arrangement of cells.

VOLTAGE....The total e.m.f. of a parallel combination of cells is equal only to the e.m.f. of any cell in the group providing they are of similar kind.

RESISTANCE.The internal resistance of cells in parallel is decreased by adding cells. The total internal resistance is equal to the internal resistance of one cell divided by the number of cells.

CURRENT....In practice cells are generally connected in parallel when the resistance of the load circuit is low so that each cell contributes its share of the total current in the circuit.

EXAMINATION - LESSON 6

1. What is a primary cell?
2. Name the materials used in some one type of primary cell.
3. (a) What determines the e.m.f. of a dry cell?
(b) What determines the useful life of a primary cell?
4. (a) What is polarization?
(b) How may polarization be reduced?
5. (a) What is meant by local action?
(b) Do you know of any remedy for local action? Explain.
6. Can a primary cell be charged and used again like a storage cell? Why?
7. What is the difference between a cell and a battery?
8. (a) When would you use a series connection of cells?
(b) What is the advantage of connecting cells in series?
(c) How is the total e.m.f. of a series combination of cells computed?
9. (a) When would you use a parallel grouping of cells?
(b) What is the advantage of a parallel connection of cells?
(c) How is the total e.m.f. of a parallel combination of cells figured?
10. If you were given 15 dry cells and asked to connect them in a group which would supply a certain circuit with an e.m.f. of 4.5 volts how would you do it? Draw a schematic diagram using symbols.